meteorological service bear to world-wide reports. The reports of a meteorological service enlarge the area of vision and *permit the forecasting of local signs*. The future will undoubtedly provide for a similar treatment of the general weather conditions of a country by the employment of telegraphic reports from a world-wide area.

AIR RADIATION.

By C. C. Hutchins and J. C. Pearson, Bowdoin College, dated July, 1904.

In 1892 one of the present writers carried out, at the request of Prof. Cleveland Abbe, some experiments for finding the radiation constant of atmospheric air. The radiation was measured from a hot, moving column of air of 1 centimeter depth in the line of sight, and as close as possible, consistent with proper screening, to the heat recording apparatus. Owing doubtless to defective surroundings, the results obtained from day to day showed considerable variation; in fact, more than could be produced artificially by changing the normal constituents of air in a closed room, such as dust and moisture, between wide limits. An average of the best results gave .00000114 small calories per second per square centimeter per degree for a thickness of 1 centimeter of the radiating layer.

In 1900 Professor Very published an extended monograph on the subject, in which very numerous experiments of his own and others are collected and discussed with the utmost skill and patience. Very's result, stated in the terms given above, at 100° excess temperature, was .00000036, or three times smaller than what we had obtained. This large difference led to a reexamination of our figures and methods, without finding anything that could account for it. An entire change of apparatus and method often leads to unexpected results, and may cause us to modify our views as to the probable error of our former consistent figures. In 1902 we constructed an entirely new apparatus, containing nothing that belonged to the old. A radio-micrometer, after Boys, was the heat receiving instrument. We avoided all suspicion of air contamination by taking air from out-of-doors. A box some 6 feet long, 2.5 feet wide, and 3 inches deep, containing a sheet iron bottom about halfway up, and covered with a single sheet of glass, was set at an angle of about 45° outside a south window. The upper end of the box was extended by a wooden chimney that projected through a slit in the window shutter. The box had trunnions at the sides, upon which it could be tilted by pulling a string. The radio-micrometer was mounted inside the shutter so that in the lowest position of the chimney the current of air that streamed up through came opposite the radio-micrometer opening. Sunlight falling upon the exposed glass cover heated the sheet iron bottom, and this in turn heated the air in contact with it, and a current of hot air was delivered through the chimney. The temperature of the hot air was obtained by a thermal junction of two thin copper and iron wires inserted in the stream, the circuit being completed through a calibrated galvanometer.

On clear, still days, excess temperatures of 50° to 60° of the hot air stream were obtained, and from the deflections produced, as compared with those produced by a lampblacked surface, at known temperature, we got values of the radiation constant that lay on both sides of the mean result of 1892. Great difficulty was experienced in getting a steady flow of hot air, and the behavior of the radio-micrometer was far from satisfactory. The experiments were discontinued when it was found that nothing new was to be learned by this method. We could at least conclude that the difference between pure air and that contained in an ordinary room with respect to radiating power was inappreciable.

The winter of 1902–3 was spent in improving the radio-micrometer, and an instrument of remarkable sensitiveness and accuracy was produced.[1]

[1] Am. Jour. Sci., Vol. XV, April, 1903.

This season we have taken up the problem anew with much improved apparatus and in very much improved surroundings. The investigation was carried out in the constant temperature room of the Searles Physical Laboratory, and the extreme range of temperature during the weeks of experiment has been less than 2°.

Finding our knowledge of the absorption of air for its own radiation in a very imperfect state, we turned our attention first to that problem.

DESCRIPTION OF APPARATUS.

The radio-micrometer was mounted upon a massive stone table, and screened from external sources of radiation. In line with the opening of the radio-micrometer was placed a truncated cone of sheet tin, 45 centimeters long, having an opening 1.5 centimeters in diameter, corresponding to the opening of the instrument, and enlarging to 5.5 centimeters at the other end. The cone is extended by a cold-drawn seamless brass tube, polished within, 280 centimeters long, and 5 centimeters internal diameter. Over the end of the brass tube is slipped a tin tube 8 centimeters in diameter, held in place by wooden rings and projecting 70 centimeters beyond the brass tube. These 70 centimeters are thickly set with diaphragms, having 5-centimeter openings, and the tube and diaphragms are carefully blackened. The legitimacy of using reflecting tubes for passing along a radiation from a distant source has often been called in question. All doubt should, however, be set at rest by recent experiments made upon the reflecting power of metals bathed in air, for long waves. Hagen and Rubens show[2] that all metals are practically perfect reflectors for radiations of great wave length, and it is certain that any difference between the reflecting power for air radiation, which is known to be of very great wave length, and the radiation from a lampblacked surface at slight temperature excess would be inoperative so far as our present purposes are concerned. Opposite the tin tube is placed the device for heating and delivering an air column. A box of wood, 100 centimeters by 35 centimeters by 14 centimeters, is mounted upon trunnions, so as to be tilted by pulling an attached string. In its vertical position, the column of hot air is delivered centrally past the opening of the long tube, but upon releasing the string the box tilts back out of the way. Beyond the air column stands a large blackened copper cube filled with water at the room temperature, and to this all temperatures are referred.

The box is filled with coils of iron wire, which are heated by a current taken from the lighting circuit, and the air flowing up through them is heated in turn. The temperature of the hot air is given by a thermometer having a very small bulb held in the stream at the height of the opening in the long tube.

EXPERIMENT TO DETERMINE THE ABSORPTION IN THE LONG TUBE FOR LAMPBLACK RADIATION.

As our values of air radiation were to be obtained in terms of radiation from a lampblacked surface, it became necessary to inquire whether the column of air in the long tube exerts any appreciable absorption upon the lampblack radiation. Langley, in his work on the temperature of the moon, has shown that a column of air 110 meters deep absorbs about 20 per cent of the rays from a blackened surface at 100° C. If the absorption follow Lambert's law, it would, in a column of air 245 centimeters deep, the depth used in the following experiment, be about 0.5 of 1 per cent, and may be neglected. The object of the following was to ascertain if the absorption changes with temperature excess.

A second blackened tank at a higher temperature than the standard tank was thrust in front of the tube and the deflection of the radio-micrometer noted. The following table gives the results:

[2] Drude's Annalen, Vol. II, 1903, p. 873.

TABLE 1.—*Depth of absorbing column, 245 centimeters.*

Excess temperature.	Mean deflection.
°	
4.06	62.6
6.62	103.5
9.55	163.0
12.79	224.0
12.18	51.63
20.91	94.17
30.60	145.3
40.90	200.3
50.00	252.5

The sensitiveness of the instrument was changed by withdrawing the condensing mirror at the point marked by the horizontal line through the table. To reduce all to a common scale, we need a reduction factor for change of sensitiveness. This will be the ratio of the deflection per degree excess for 12.79° to the deflection per degree excess for 12.18°, assuming that the radiation rate is the same for these two near temperatures. After applying this factor and dividing each deflection by its corresponding temperature, we obtain the following:

TABLE 2.

Excess temperature.	Deflection per degree excess.
°	
4.06	15.42
6.62	15.63
9.55	17.07
12.79	17.51
20.91	18.61
30.60	20.01
40.90	20.23
50.00	20.86

McFarlane gives a table[3] showing the radiation in small calories per second per square centimeter of a blackened surface. For 50° excess McFarlane's figure is .000326. Multiplying the numbers in the second column of Table 2 by such a factor as will reduce the last to .000326, we plot a curve with excess temperatures as values of x, and the observed radiation rates, derived as above, as values of y, and along with it a second curve from McFarlane's observations.

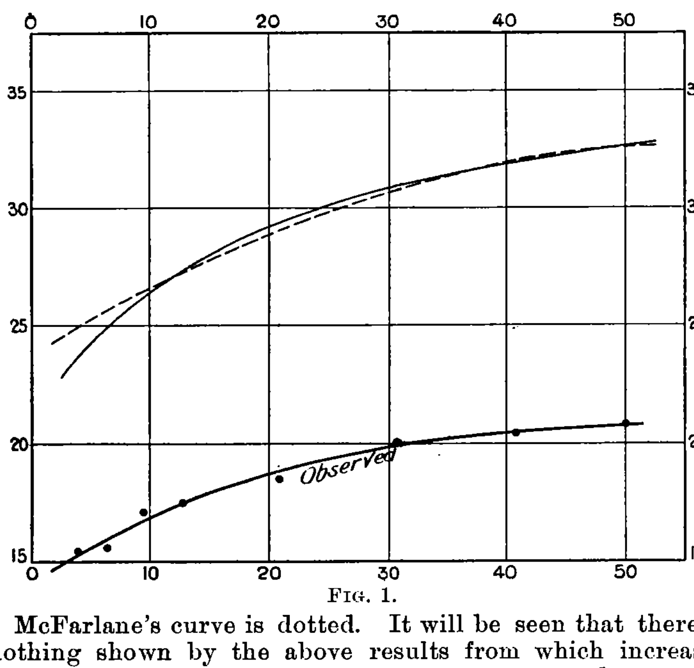

FIG. 1.

McFarlane's curve is dotted. It will be seen that there is nothing shown by the above results from which increased absorption at smaller excess temperatures can be argued. Considering the widely different methods by which these curves were derived, their agreement is quite striking. We feel sure, then, that we shall commit no appreciable error in effecting a comparison of air and lampblack radiation if we assume that the latter is unabsorbed by columns of air of the depth used in our experiments. In fact, difference in the manner of preparation of the lampblack surfaces is known to cause greater radiation differences than are shown here.

[3] Proc. Roy. Soc. 1872, p. 93.

ABSORPTION OF AIR FOR ITS OWN RADIATION.

The radiation of air can not be properly considered apart from the question of the rate at which its own radiation is absorbed. Very[4] obtains a change of deflection per foot of increase of radiating depth of 8.3, 10.0, 8.2, 10.4, —1.2, the depths being 1, 2, 3, 4, and 5 feet, respectively. Disregarding the rather discordant character of these figures, he rejects the negative change for 5 feet entirely on what seems somewhat uncertain grounds. We have sought to avoid the difficulty of absorption in the radiating column itself by measuring the depth of the absorbing layer from the center of a radiating column only 10 centimeters deep. Hence, if there be any outstanding error, it must be very small and, we believe, negligible.

A complete example of the method of proceeding is here given: The long tube being in place and carefully covered with asbestos steampipe covering, the current was turned on in the heating box, and at the end of half an hour the following deflections were obtained:

TABLE 3.

Deflections.	
55.0	Date, June 29; air column, 491 centimeters; hot air temperature, 142°; room temperature, 20.5°; hot air excess, 121.5°.
52.0	
54.5	
53.0	
55.5	
55.5	
52.0	
55.0	
56.0	
Mean.. 54.33	

The warm, blackened tank gave the following deflections:

TABLE 4.

Temperature, cold tank.	Temperature, hot tank.	Deflections.
20.56	24.05	106.0
....	24.10	101.5
....	24.18	109.5
....	24.22	106.5
20.58	24.24	104.5
20.57	24.16	105.6

The mean deflection corresponding to 1° excess temperature of air is

$$\frac{54.33}{121.5} = 0.4472.$$

The excess temperature of the lampblacked surface is

$$24.16 - 20.57 + 0.59 = 4.18$$

where $+ 0.59$ is the thermometer correction. Hence, the deflection per degree excess for the lampblacked surface is

$$\frac{105.6}{4.18} = 25.26.$$

Finally, the ratio of the hot air radiation to that from the blackened surface is

$$\frac{.4472}{25.26} = .01770.$$

On July 1 we obtained .0159; on July 2, .0177; on July 8, .01734; the average of six days being .01685.

The absorbing column was then made 245 centimeters, 127 centimeters, 61 centimeters, and 30 centimeters, and the same method followed for each distance, in each case the observations being distributed over several days. The results are tabulated below:

[4] Atmospheric Radiation, p. 45.

TABLE 5.

Absorbing column.	Mean ratio.
Centimeters.	
30	.0332
61	.0278
127	.0195
245	.0169
491	.0168

Plotting these observations with the numbers in the first column of Table 5 as abscissas and the numbers in the second column as ordinates, we obtain the following curve:

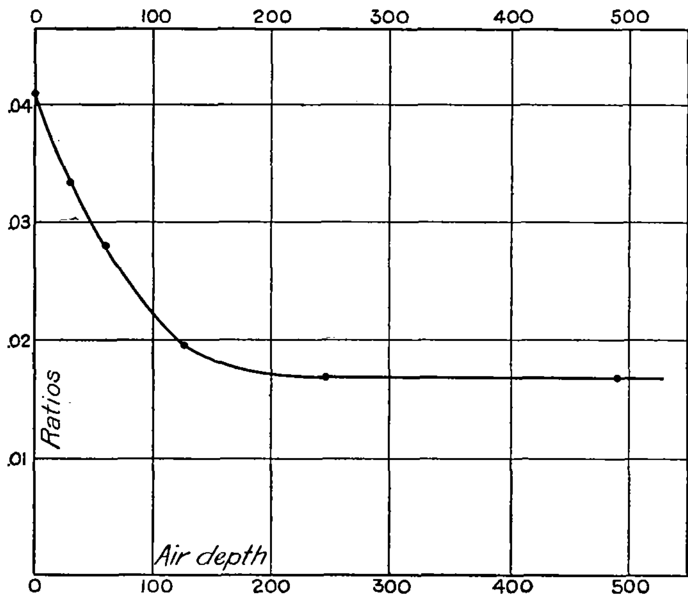

FIG. 2.

An inspection of fig. 2 reveals a very important feature of air radiation hitherto unknown; namely, that some 60 per cent of its own radiation is absorbed by a column as thin as 245 centimeters, the remaining 40 per cent being freely transmitted as though coming from a black body. We have plotted the ratios of air radiation to lampblack radiation per degree of excess temperature. The point where the curve cuts the Y-axis will correspond to the ratio at zero depth of absorbing column, and is important to know. This point may be calculated as follows:

Let

$L =$ radiation from lampblack,

$b =$ radiation of air for which absorption is neglected,

$J' =$ characteristic radiation from hot air, that is, b neglected.

Then at zero depth, $b + J'$ is the total radiation from air. Lambert's law is $J = J' a^d$, and we have plotted the quantity $\frac{b+J'}{L}$ versus d. Taking $d_1 = 1$, and $d_2 = 2.033$, we have

$$\frac{b+J_1}{L} = 0.0332 = \frac{b+J'a}{L} \qquad (1)$$

$$\frac{b+J_2}{L} = 0.0278 = \frac{b+J'a^{2.033}}{L} \qquad (2)$$

$$\frac{b}{L} = 0.0169 \qquad (3)$$

We wish to find the value of $(b + J')/L$.

From (3) $\quad b = 0.0169\ L$

whence, from (1) $\quad J'a = 0.0163\ L$

and $\quad a = 0.0162\ L/J'$

Substituting the values of a and b in (2), we get

$$0.0109\ L = \frac{(0.0163\ L)^{2.033}}{(J')^{1.033}}$$

whence

$$J' = L\left[\frac{(0.0163)^{2.033}}{0.0109}\right]^{\frac{1}{1.033}}$$

This gives

$$\frac{b+J'}{L} = 0.0409$$

This point fits in a perfectly satisfactory manner upon a smooth curve drawn through the observed points.

What the course of absorption may be beyond a depth of 500 centimeters, we have no means at present of judging. It may be suggested that the compound nature of air is responsible for its peculiar manner of absorption. Perhaps its contained water vapor is the substance radiating like a black body, and that apart from this, the strongly curved portion of our diagram shows the characteristic behavior of its prominent gaseous constituents. If this be true, it follows that the radiation of pure dry air is effective only at comparatively slight depths. The amount of moisture in the air during this course of experiments was considerable, the relative humidity not varying much from 78.2. It may be that water vapor so little removed from its point of saturation no longer behaves as a true gas, but as an aggregate of particles, in which case it would transmit all rays with considerable freedom, the particles producing a scattering effect merely. The accepted explanation of the color of the sky favors this view.

We have now to discuss the change of radiation of air with change of temperature. By introducing a variable resistance into the circuit of the heating box, the temperature of the heated air could be changed at will. A mean of five to ten consistent observations was taken for each temperature and the results tabulated as follows:

TABLE 6.

Excess temperature.	Mean deflection.
o	
22.5	18.55
28.2	24.9
43.2	40.9
72.1	77.9
87.0	105.7
125.5	185.9

Plotting deflections versus temperatures from Table 6, we obtain the following curve:

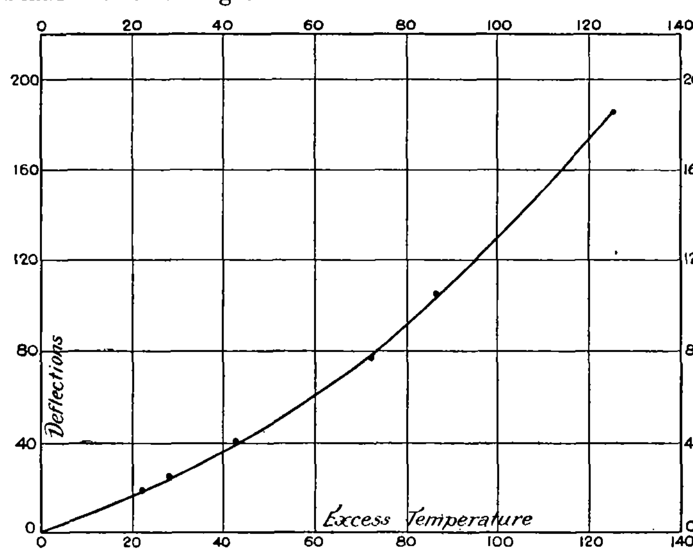

FIG. 3.

Calling D the deflection and t the temperature, the equation of this curve may be written,

$$D = At + Bt^2 + Ct^3,$$

from which, using three observations, we obtain

$$D = .7185\,t + .486\,t^2\,(10^{-2}) + .96\,t^3\,(10^{-5}),$$

the logarithmic coefficients being

$$\log A = 9.856448 - 10,$$
$$\log B = 7.687127 - 10,$$
$$\log C = 4.984735 - 10.$$

From the above the relative ratio of air radiation per degree at different temperatures may be found.

For $t = 1°$, we have $dD/dt = 0.728$.

For $t = 100°$, we have $dD/dt = 1.98$.

Hence the radiation per degree at 100° is $1.98/0.728 = 2.72$ times greater than at 1°.

There remains before computing the value of the radiation constant to find the temperature gradient of the hot air column in the line of sight; laterally, the central portion of the air column only was used, and no correction in that direction is required. A thermal junction of thin copper and iron wires was moved by steps through the heated air column, and the readings of a galvanometer, through which the junction was connected, noted. The edge of the opening in the air chimney being called 0, its center would be at 5. The following readings were obtained:

TABLE 7.

Distance.	Deflection.
5.0	155
4.0	155
3.0	155
2.0	155
1.0	149
0.5	124
0.2	105
0.0	90
—0.2	75
—0.5	50
—1.0	22

The air flowing up past the outside of the warmed box gave the deflections for negative values of distance; the integral of these was nearly sufficient to balance the loss for less temperature within the range of positive values of the distance. By plotting a curve and integrating the positive and negative values with reference to distance, and radiation rate as derived from fig. 3, we find the actual air column to be 0.967 as effective as a column 10 centimeters deep, and at a temperature measured at its center.

We are now prepared to calculate the radiation constant, h. Assume that this is wanted for an excess temperature of 100°, a depth of 1 centimeter, and zero absorbing column. We have:

Average of all excess air temperatures observed	= 122°
Deflection for 122° from fig. 3	= 179
Deflection for 100° from fig. 3	= 130
Radiation per degree from lampblack at 4° excess; average	= .000249 (McFarlane.)
Ratio of air to lampblack radiation for zero absorbing column, from fig. 2	= .041

Therefore, $h = (130/179)\,(.000249)\,(0.1)\,(.041)\,(0.967)$
$= 0.000000717$ water-gram-degrees per square centimeter per second per degree excess temperature.

For 1° this becomes 0.000000264, and may be found with great facility from the curves given, or from their equations, for any temperature or depth of absorbing column within the limits of our observations.

If our surmise be correct that the freely transmitted part of moist air radiation is from its contained water vapor, amounting to 40 per cent of the whole, then the above numbers would become for dry air, 0.00000043 and 0.00000016, respectively.

NOTES AND EXTRACTS.

OBSERVATIONS AT TASIUSAK.

The Danish Government has recently published the record of meteorological, magnetic, and auroral observations made at Tasiusak, in the district of Angmagsalik, during the years 1898–99. This district was first explored and charted in 1884–85 by G. Holm, who found there a hitherto unknown tribe of Esquimaux. Consequently, in 1894, the Danish Government established here a commercial station and a mission. The station at Tasiusak is on the southwest shore of a small fiord on the southern coast of the island of Angmagsalik. The terminal moraines of great glaciers approach within 20 miles on the northwest and 50 miles on the north. The Atlantic Ocean occupies a semicircle of the horizon from northeast to southwest. An arctic current flows between Tasiusak and Iceland, whose nearest point is 300 miles to the eastward. The latitude of the station is 65° 36′ 40″ north, longitude 37° 33′ 26″ west of Greenwich. The cistern of the mercurial barometer is 17.3 meters above mean sea level. The records of the Richard self-recording instruments are published for each hour of the day, in full from November 1, 1898 to May 17, 1899. But observations in general are at hand for seven years during the interval 1883–1900, or whenever scientific expeditions have remained at that place. Some of the more remarkable meteorological measurements at the station are elucidated in this report by means of charts of the barometric regions over the North Atlantic Ocean. During seven years it was very rare to find a month where the maximum temperature did not rise above that of melting ice. Even in January and February, although the minimum temperatures are 28°, 29°, or 30° below zero on the centigrade scale, yet the maxima are 3°, 4°, or 5° above; that is to say, from 37° to 41° Fahrenheit. The relative humidity of the air falls as low as 11 per cent in September and November, but in other months it ranges between 25 and 46. From November to February the wind blows from the northern portion. In April and May the most frequent winds are south and west, but calms are still more frequent, amounting to from 40 to 50 per cent in November and February. The greatest velocity of the wind, measured by the Robinson anemometer, occurred during the storm of November 25–26, 1898, and amounted to 47.4 meters per second, or 95 miles per hour. At that time a center of low pressure was moving eastward, just to the north of Tasiusak and over Iceland. In general the centers of low pressure passed to the west of Stykkisholm, on the west coast of Iceland, twenty-two times during the winter of 1898–99, but to the south of Stykkisholm eighteen times. Those that pass to the west undoubtedly pass near Tasiusak. Elaborate descriptions are given of the aurora borealis, and the statistics show that the station is located in the northern part of the zone of maximum frequency, or even entirely north of this zone, which traverses Greenland at the sixty-first degree of latitude, and then passes between Iceland and Greenland, probably over the island of Jan Mayen and continues on between the northern part of Norway and the island of Spitzbergen.—*C. A.*

CLIMATOLOGY OF BALTIMORE, MD.

For some years past Dr. O. L. Fassig has been compiling a work on the climatology of Baltimore and its vicinity. This report will form volume 2 of the reports of the Maryland State Weather Service, and is already in press. Progress toward the completion of the report has been delayed, owing to the fact that almost all the work must be done outside office hours, that is to say, at night time. Unfortunately, on two occasions, fire has destroyed many finished plates, but nearly all the numerical calculations have been completed, and a final draft of the outline of the report can be submitted. The complete